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WILLIAM HUGGINS, ESQ., F.R.S., President, in the Chair.

Robert John Baillie, Esq., 10 Bolton Place, Carlisle;
H. Vere Barclay, Esq., 6 Disraeli Terrace, Putney;
Rev. Daniel Dutton, Sandbach, Cheshire;
Samuel Heywood, Esq., 171 Stanhope Street, Hampstead Road;
Louis Stromeyer Little, Esq., M.D., B.A., 18 Park Street, Grosvenor Square;
Robert Pearce, Esq., Church Court Chambers, Old Jewry;
Commander William James Lloyd Wharton, H.M. Surveying Ship "Fawn;"
Jesse Young, Esq., Stibbington House, Wantsford,

were balloted for and duly elected Fellows of the Society.

Theory of the Horizontal Photoheliograph, including its application to the determination of the Solar Parallax by means of Transits of Venus. By Professor William Harkness, U. S. Navy. (Abstract.)

(*Communicated by the Astronomer Royal.*)

The term "Horizontal Photoheliograph" is used to designate that form of photoheliograph which, it is believed, was first employed by the late Professor Winlock, and which consists essentially of a fixed telescope, whose optical axis is accurately horizontal and in the meridian, and whose objective is directed towards the same side of the zenith as the elevated pole; the Sun's rays being reflected into the telescope by a suitable heliostat. The sensitive plate for the reception of the photographic image is, of course, situated at the chemical focus of the telescope,

the plane of the plate being perpendicular to, and its centre coinciding with, the optical axis of the telescope.

The heliostat mirror consists of a piece of highly polished (but unsilvered) glass, whose two surfaces make an angle of about sixty minutes with each other. The front surface is worked as truly plane as possible, and serves to reflect the solar rays through the object-glass to the photographic plate. In working the back surface, no particular pains are taken; and, on account of its inclination to the front surface, any light reflected from it is thrown entirely away from the photographic plate. The object-glass is corrected for the chemical, and not for the visual rays. The distance between the object-glass and mirror is made as small as possible, consistently with keeping the latter clear of the shadow of the former. The sensitive surface of the photographic plate faces the object-glass, while the rays from the Sun are reflected by the mirror through the object-glass, and after traversing the reticule, they form an image upon the photographic plate.

The reticule consists of a system of squares, formed by the intersection of two systems of very fine straight lines, which are drawn upon one side of, and respectively parallel to, the edges of a thin square plate of plano-parallel glass. In each of these linear systems the number of lines is odd, and the middle line is drawn through the centre of the plate. This reticule is fixed with its ruled surface toward, parallel to, and two or three millemeters distant from, the sensitive surface of the photographic plate. Moreover, one of the two systems of lines is set as nearly as possible vertical, and its inclination is accurately determined; and, to render assurance doubly sure, a plumb-line, consisting of a silver wire about 0·05 of a millemeter in diameter, is suspended between the reticule and the photographic plate, in such a position that it may hang freely, and at the same time be very nearly in the vertical plane passing through the centres of the reticule and object-glass. As the light from the object-glass traverses the reticule before it reaches the photographic plate, the shadow, both of the reticule and of plumb-line, is impressed upon every picture taken with the apparatus; and thus three different ends are gained: First, by comparing the squares of the reticule with the corresponding ones upon the picture, everything relating to the shrinkage of the collodion can be determined; secondly, the impression of the plumb-line, and also that of the vertical lines, furnishes upon each picture a fixed direction from which to measure angles of position; and, thirdly, the intersection of the middle vertical with the middle horizontal line furnishes a fixed point, which in the paper is designated as the centre of the plate. To determine the zenith distance and azimuth of this point, it is necessary to measure the zenith distance and azimuth of the corresponding point of the reticule, as seen from the second principal point of the object-glass. For that purpose, the mirror is temporarily removed, and a

transit instrument is set up in front of the object-glass in prolongation of its axis. The object-glass thus becomes a collimator to the transit instrument, through the eyepiece of which the lines of the reticule may be observed as if they were at an infinite distance. It should be remarked, however, that as the reticule is slightly inside the visual focus of the object-glass, it is not generally possible to obtain perfectly distinct vision of its lines and of the wires of the transit at the same time. This difficulty is obviated by marking the intersection of the middle vertical and middle horizontal lines of the reticule in such a distinct manner, that the slight maladjustment of focus does not prevent it from being seen. Then, by means of the transit, the reticule is adjusted so that the point in question is very approximately in the meridian, and at a zenith distance of ninety degrees. Finally, the exact azimuth and zenith distance of the point are measured.

The remainder of Professor Harkness's paper, which will probably be given *in extenso* in the *Memoirs* of the Society, is occupied with a full and detailed explanation, with diagrams, of the principle of the instrument, and of the methods of measurement of the photographs.

Micrometrical Measures of Double Stars. By George Knott. (Abstract).*

I have the honour of presenting to the Royal Astronomical Society a short series of Micrometrical Measures of Double Stars, taken between the years 1860 and 1873, at my former residence, Woodcroft, Cuckfield.

The Observatory, detached at some little distance from the house, and commanding a good horizon view, stood at an elevation above the sea level of about 370 feet, and in the approximate position, latitude $51^{\circ}\ 0'\ 41''$ North, longitude $0^{h}\ 0^{m}\ 34^{s}$ West.

The Equatoreal has an object-glass of $7\frac{1}{3}$-inches clear aperture and $110\frac{1}{2}$-inches focal length, by Messrs. Alvan Clark and Sons of Boston, U.S.A., and is a fine specimen of the makers' skill. It was formerly in the possession of the Rev. W. R. Dawes.

The filar, or parallel-wire, micrometer, employed in the following measures, was made for me by the late Mr. Dollond. It has a position-circle of $3\frac{1}{2}$-inches diameter, reading, by two verniers, to tenths of a degree, and the angle of position is taken by placing the two stars under observation centrally parallel between two thick wires, about $13''$ apart. At right angles to the position-wires are the webs for distance-measures, of which two, one

* The Paper will probably appear *in extenso* in the *Memoirs* of the Society.—Ed.

fine and the other coarse (the latter for measures of faint objects, but rarely used), are carried by each screw.

The screw-heads, divided to 100 parts, are of nearly two inches diameter, and are fitted with bolts, so that either web may be fixed as zero-wire, while the other is used in making the measures. There is a battery of seven eye-pieces, with magnifying powers from 115 to 515, and, by the use of an achromatic concave Barlow-lens, the magnifying power may be increased in the proportion of about 2·25 to 1. The micrometer is also fitted with a convenient slipping-piece. The value of one revolution of the screw is 18″·2949, and with the Barlow-lens, 8″·0765.

In reducing the observations, the arithmetical mean is taken as the mean for the night. To each individual measure a number is assigned (1–9) expressive of its estimated worth, and the sum of these numbers is taken as the weight of the set, which is thus a function of the number of observations and of the estimated value of each measure. In forming the "Mean results" (or mean of several nights' measures), this number is introduced as the *combination weight*.

Being interested in the observation of Variable Stars, I found it convenient to adopt Mr. Pogson's standard scale, or Argelander's scale extended to the lower magnitudes by the adopted light-ratio 2·512. (*Monthly Notices*, vol. xvii. p. 15.) The numbers expressing the magnitudes will be found therefore to lie generally between those of Σ on the one hand, and that of H. and Sm. on the other, the difference being more marked in the lower magnitudes. Although, for convenience, the magnitudes are expressed decimally, they must not be regarded as making any pretensions to very close accuracy.

Cuckfield,
1877, *January* 11.

On the Orbit of α Centauri. By J. R. Hind.

Having been lately favoured by Lord Lindsay with the results of two sets of measures of the angle of position of *α Centauri* made with the heliometer at the Mauritius in November 1874, during his Lordship's expedition for the observation of the transit of *Venus*, I have attempted a further approximation to the elements of this most interesting binary.

I employed the last orbit by Mr. Eyre B. Powell, of Madras, in the formation of equations of condition, for the epochs of the most reliable mean results, depending on the measures of Sir John Herschel, Captain Jacob, Mr. Powell, and Lord Lindsay, at the same time admitting the angle for 1752·2 given by Lacaille's Right

Ascension and Declination. The elements obtained by the solution of the equations are as follow :—

Peri-astron passage	1874·85
	° ′
Node	21 48·0
Node to peri-astron on orbit	59 32·1
Inclination	82 18·4
Angle of eccentricity	41 51·5
or $e = 0{\cdot}6673$	
	″
Semi-axis major	21·797
	yrs.
Period of revolution	85·042

The following is the comparison with observations :—

		Position (C−O).	Distance (C−O).	
		°	″	
Lacaille	1752·2	−0·8	−4·7	
Brisbane	1825·0	−4·0	+0·2	
Johnson	1830·0	−2·1	+0·2	
Cape	1833·0	−2·9	+0·1	
Herschel	1836·00	−2·6	...	
,,	1836·06	...	−0·23	
Cape	1840·0	+3·9	−3·22	
Jacob	1846·75	−2·7	−1·07	
,,	1848·02	−2·6	−0·28	
,,	1850·83	−2·1	−0·32	
,,	1852·23	−2·7	−0·15	
,,	1856·27	+1·6	−0·16	
,,	1857·15	+1·0	+0·03	
Powell	1859·38	+0·9	−0·98	
,,	1860·11	+1·0	−0·18	
,,	1861·05	+1·0	+0·06	
,,	1862·21	−0·7	+0·11	
,,	1863·08	−0·7	+0·29	
,,	1863·11	−4·9	−0·34	Position preferred by Powell to last
,,	1870·10	−3·0	+0·23	
Lindsay	1874·85	+0·4	...	

It will be remarked that Lord Lindsay's measures fall exactly at the computed time of nearest approach of the component stars in the real orbit. Probably a somewhat closer

representation of the observed angles and distances might be obtained by repeating the process upon which the above elements were deduced, but I defer any further computation in the hope of soon receiving measures made after the passage of the peri-astron.

Lord Lindsay's epoch, as used above, is,

1874·85 34°·17

If, for the annual parallax, a mean of Henderson's value, as corrected by Peters, and that of Moesta, be taken, giving 0″·928, we find the mass of this system = 1·79 × ⊙'s mass, and for the semi-axis major of the orbit 23·49.

Ephemeris for Determining the Positions of the Satellites of Uranus, 1877.

By A. Marth, Esq.

(*Communicated by A. C. Ranyard, Esq.*)

Greenw. Noon. 1877.	*p*	Ariel. log *a*	Ariel. log *b*	Umbriel. log *a*	Umbriel. log *b*	Titania. log *a*	Titania. log *b*	Oberon. log *a*	Oberon. log *b*
Jan. 25	10·48	1·1811	0·7569	1·3251	0·9009	1·5400	1·1158	1·6662	1·2420
30	10·41	·1817	·7613	·3257	·9053	·5406	·1204	·6668	·2464
Feb. 4	10·34	·1821	·7656	·3261	·9096	·5410	·1245	·6672	·2507
9	10·27	·1823	·7697	·3263	·9137	·5412	·1286	·6674	·2548
14	10·21	·1823	·7736	·3263	·9176	·5412	·1325	·6674	·2587
19	10·14	·1822	·7772	·3262	·9212	·5411	·1361	·6673	·2623
24	10·07	·1818	·7806	·3258	·9246	·5407	·1395	·6669	·2657
Mar. 1	10·01	·1812	·7836	·3252	·9276	·5401	·1425	·6663	·2687
6	9·95	·1804	·7862	·3244	·9302	·5393	·1451	·6655	·2713
11	9·89	1795	·7885	·3235	·9325	·5384	·1474	·6646	·2736
16	9·83	·1784	·7903	·3224	·9343	·5373	·1492	·6635	·2754
21	9·78	·1772	·7918	·3212	·9358	·5361	·1507	·6623	·2769
26	9·73	·1758	·7928	·3198	·9368	·5347	·1517	·6609	·2779
31	9·69	·1743	·7934	·3183	·9374	·5332	·1523	·6594	·2785
Apr. 5	9·66	·1727	·7935	·3167	·9375	·5316	·1524	·6578	·2786
10	9·63	·1710	·7932	·3150	·9372	·5299	·1521	·6561	·2783
15	9·61	·1692	·7925	·3132	·9365	·5281	·1514	·6543	·2776
20	9·60	·1673	·7913	·3113	·9353	·5262	·1502	·6524	·2764
25	9·59	·1654	·7896	·3094	·9337	·5243	·1486	·6505	·2748
30	9·59	·1635	·7878	·3075	·9318	·5224	·1467	·6486	·2729
May 5	9·60	1·1615	0·7854	1·3055	0·9294	1·5204	1·1443	1·6466	1·2705

a and b are the major and minor semi-axes of the apparent orbits of the satellites, expressed in seconds of arc; p_o is the position-angle of the major axes. The longitudes ω of the satellites in their orbits, reckoned from the points of their greatest northern elongations, are the following:—

Greenwich, Noon.	Ariel. ω	diff.	Umbriel. ω	diff.	Titania. ω	diff.	Oberon. ω	diff.
	°	°	°	°	°	°	°	°
Jan. 25	168·28		330·37		19·65		248·04	
		714·16		434·32		206·72		133·67
30	162·44		44·69		226·37		21·71	
		·15		·31		·72		·66
Feb. 4	156·59		119·00		73·09		155·37	
		·15		·31		·72		·66
9	150·74		193·31		279·81		289·03	
		·14		·31		·72		·66
14	144·88		267·62		126·53		62·69	
		·13		·30		·72		·66
19	139·01		341·92		333·25		196·35	
		·13		·30		·72		·66
24	133·14		56·22		179·97		320·01	
		·12		·30		·72		·66
Mar. 1	127·26		130·52		26·69		103·67	
		·12		·30		·71		·66
6	121·38		204·82		233·40		237·33	
		·12		·29		·72		·66
11	115·50		279·11		80·12		10·99	
		·12		·30		·72		·66
16	109·62		353·41		286·84		144·65	
		·11		·29		·72		·67
21	103·73		67·70		133·56		278·32	
		·10		·30		·72		·66
26	97·83		142·00		340·28		51·98	
		·11		·29		·72		·67
31	91·94		216·29		187·00		185·65	
		·11		·30		·73		.67
Apr. 5	86·05		290·59		33·73		319·32	
		·11		·29		·72		·68
10	80·16		4·88		240·45		93·00	
		·10		·30		·73		·67
15	74·26		79·18		87·18		226·67	
		·11		·30		·73		·68
20	68·37		153·48		293·91		0·35	
		·11		·30		·74		·69
25	62·48		227·78		140·65		134·04	
		·11		·31		·74		·68
30	56·59		302·09		347·39		267·72	
		714·12		434·30		206·74		133·69
May 5	50·71		16·39		194·13		41·41	

These values must be interpolated for the times for which the position of the Satellites are required. The angles of position p and distances s are then found by means of the equations—

$$s \sin (p_o - p) = b \sin \omega.$$
$$s \cos (p_o - p) = a \cos \omega.$$

The interpolation of the values of ω may be facilitated by the following tables, which give the motion of ω for every even hour of the five days' interval:—

Ariel, diff. = 714°·12.

h	0d	1d	2d	3d	4d
	°	°	°	°	°
0	0·00	142·82	285·65	68·47	211·30
2	11·90	154·73	297·55	80·37	223·20
4	23·80	166·63	309·45	92·28	235·10
6	35·71	178·53	321·35	104·18	247·00
8	47·61	190·43	333·25	116·08	258·90
10	59·51	202·33	345·16	127·98	270·81
12	71·41	214·24	357·06	139·88	282·71
14	83·31	226·14	8·96	151·79	294·61
16	95·22	238·04	20·86	163·69	306·51
18	107·12	249·94	32·77	175·59	318·41
20	119·02	261·84	44·67	187·49	330·32
22	130·92	273·75	56·57	199·39	342·22
24	142·82	285·65	68·47	211·30	354·12

Umbriel, diff. = 434°·28.

h	0d	1d	2d	3d	4d
	°	°	°	°	°
0	0·00	86·86	173·71	260·57	347·42
2	7·24	94·09	180·95	267·81	354·66
4	14·48	101·33	188·19	275·04	1·90
6	21·71	108·57	195·43	282·28	9·14
8	28·95	115·81	202·66	289·52	16·38
10	36·19	123·05	209·90	396·76	23·61
12	43·43	130·28	217·14	304·00	30·85
14	50·67	137·52	224·38	311·23	38·09
16	57·90	144·76	231·62	318·47	45·33
18	65·14	152·00	238·85	325·71	52·57
20	72·38	159·24	246·09	332·95	59·80
22	79·62	166·47	253·33	340·19	67·04
24	86·86	173·71	260·57	347·42	74·28

Titania, diff. = 206°·70.

h	0d	1d	2d	3d	4d
	°	°	°	°	°
0	0·00	41·34	82·68	124·02	165·36
2	3·45	44·79	86·13	127·47	168·81
4	6·89	48·23	89·57	130·91	172·25
6	10·34	51·68	93·02	134·36	175·70
8	13·78	55·12	96·46	137·80	179·14
10	17·23	58·57	99·91	141·25	182·59
12	20·67	62·01	103·35	144·69	186·03
14	24·12	65·46	106·80	148·14	189·48
16	27·56	68·90	110·24	151·58	192·92
18	31·01	72·35	113·69	155·03	196·37
20	34·45	75·79	117·13	158·47	199·81
22	37·90	79·24	120·58	161·92	203·26
24	41·34	82·68	124·02	165·36	206·70

Oberon, diff. = 133°·68.

h	0d	1d	2d	3d	4d
	°	°	°	°	°
0	0·00	26·74	53·47	80·21	106·94
2	2·23	28·96	55·70	82·44	109·17
4	4·46	31·19	57·93	84·66	111·40
6	6·68	33·42	60·16	86·89	113·63
8	8·91	35·65	62·38	89·12	115·86
10	11·14	37·88	64·61	91·35	118·08
12	13·37	40·10	66·84	93·58	120·31
14	15·60	42·33	69·07	95·80	122·54
16	17·82	44·56	71·30	98·03	124·77
18	20·05	46·79	73·52	100·26	127·00
20	22·28	49·02	75·75	102·49	129·22
22	24·51	51·24	77·98	104·72	131·45
24	26·74	53·47	80·21	106·94	133·68

On the Conjunction of Venus and λ Geminorum.

By John I. Plummer.

In a late number of the *Monthly Notices* (vol. xxxvi. p. 340) Mr. Dunkin has called attention to the proposal of Dr. Krüger, that astronomers in either hemisphere should avail themselves of the near approach of *Venus* to the bright star λ *Geminorum*, at a time when the planet was but little distant from the Earth, with the view of determining the solar parallax. It may, therefore, be of interest to the Fellows of the Society to record the degree of success that has attended the observations at the Orwell Observatory. The plan which it was proposed to pursue on the occasion, was to measure differences of declination of the planet and star, commencing as soon as *Venus* had attained an altitude of 20°, to be continued so long as circumstances would permit, since with the large aperture at my command (10 inches), no difficulty would be experienced in following up the observations to the time of actual conjunction in Right Ascension. Five comparisons of each limb of the planet with the star were to be made with a parallel-wire micrometer (power 315) alternately, and it was confidently expected that the probable error of the mean of each set would not exceed $\frac{1}{10}$th of a second of arc. Such a series would have been useful if corresponding observations had been made at any position in the southern hemisphere, and failing a preconcerted arrangement with a southern station, was the most satisfactory scheme that suggested itself to my mind.

Unhappily it was discovered on the morning of August 18, that the definition of the planet and star was not sufficiently sharp for the desired degree of accuracy to be ensured, and was at times so indifferent that I was doubtful whether measures avowedly so delicate ought not to be discontinued. They were, however, persevered in until $18^h\ 46^m$ G.M.T., when cirrus cloud overspread the sky, obliterating both objects for several hours. By this time 10 sets of 5 comparisons each had been obtained, and, although these may not fully serve the end for which they were undertaken, they quite unexpectedly throw light upon a question to which I have always attached some interest.

The following is a comparison of the observations with the Ephemeris of the *Nautical Almanac*, which has been made in order to test the reliability of the individual sets, assuming, for the purposes of reduction, the solar parallax equal to $8''{\cdot}90$, and the apparent declination of the star $+16°45'51''{\cdot}84$. It should be remarked that the north limb of the planet was full, and that the correction for defective illumination of the south limb was so small as to be quite insensible.

Venus, N.L. — λ *Geminorum*.

Set.	Greenwich Mean Time of Observation. h m s		Uncorrected Difference of N.P.D. ′ ″	Assumed Semidiameter of *Venus*. ″	Differential Refraction Correction. ″	Correction for Parallax.	Observed N.P.D. of *Venus*— Calculated N.P.D.	Weight.
1	16 27 15·7	(*a*)	+1 46·587	+20·048	+0·116	−14·330	−0·315	4
3	16 56 40·5		+1 43·562	+20·042	+0·086	−13·891	+0·039	3
5	17 15 4·9	(*b*)	+1 42·144	+20·037	+0·074	−13·625	+0·729	2
7	17 53 31·4		+1 38·161	+20·029	+0·058	−13·111	+1·115	2
9	18 21 56·6		+1 34·259	+20·023	+0·049	−12·778	+0·396	3

Venus, S.L. — λ *Geminorum*.

2	16 39 45·2		+2 26·611	−20·045	+0·141	−14·141	+1·094	3
4	17 5 6·4		+2 22·991	−20·040	+0·111	−13·771	+0·382	3
6	17 30 31·9		+2 19·915	−20·034	+0·092	−13·413	+0·219	2
8	18 9 16·3	(*c*)	+2 15·360	−20·025	+0·074	−12·913	+0·062	4
10	18 39 56·4	(*d*)	+2 10·274	−20·019	+0·065	−12·586	−1·611	1

Remarks.—(*a*) Sky quite clear and images fairly steady.—(*b*) Shortly after sunrise the definition of the planet became gradually worse, and the star faint, large, and trembling.—(*c*) Definition of *Venus* much improved, and the star which had nearly disappeared is now smaller and more easily seen.—(*d*) Images bad again: cirrus cloud completely hid the star after four bisections, which were all that could be obtained with difficulty for this set. It is from the consideration of these remarks alone that weights have been assigned in the last column.

In comparing the observations with the Ephemeris we may obviously employ whatever value of the planet's semidiameter we please, and I have, therefore, adopted that which best satisfies the observations themselves, namely 8″·698 at mean distance. This is very slightly larger than that determined by myself with the double-image micrometer in 1873 (8″·661), but is less than the well-known determination of Mr. Maine (8″·775). In spite of the unsatisfactory state of the sky, an analysis of the individual bisections shows that the probable error of a single set of observations does certainly not exceed 0″·21, and it was, therefore, very disappointing to deduce the marked discordances that occur in the 7th column. If, however, we assume that the apparent semidiameter of the planet, owing to irradiation, did not remain constant before and after sunrise, but diminished in proportion as the neighbouring sky became more and more illuminated, an explanation of these anomalous results is possible, and their true significance will be apparent when exhibited in the following form :—

			Weight as before.	Approx. G.M.T. of Observation. h	m	Group.
Mean excess of planet's observed N.P.D. over that of Ephemeris, giving weights as above	...	+0·268				
Apparent excess of observed semidiameter over that assumed in the previous reductions.	Set 1	+0·583	4	16	27	1
	„ 2	+0·806	3	16	40	
	„ 3	+0·229	3	16	57	2
	„ 4	+0·114	3	17	5	
	„ 5	−0·461	2	17	15	
	„ 6	−0·049	2	17	31	3
	„ 7	−0·847	2	17	54	
	„ 8	−0·206	4	18	9	
	„ 9	−0·128	3	18	22	
	„ 10	−1·879	1	18	40	
Greenwich Mean Time of Sunrise at Orwell Park		...		16	44	

Not only do these figures show a gradual decrease of the apparent semidiameter, and a more sudden diminution at the moment of sunrise, but dividing them into three groups and taking the mean of each we shall arrive at a pretty fair approximation to the amount of variation due to the several states of illumination of the sky. Thus the mean of sets 1 and 2 shows that before sunrise the contacts were made too *remote*, and the measured semidiameter was consequently too great, by the quantity 0″·679 (Wt. 7). The next three sets, which were taken when the Sun was very low, yield an average of only 0″·013 (Wt. 8), as the excess of the measured semidiameter over the assumed value. The mean of the sets 6–9, observed after the Sun had fairly freed itself from the haze of the horizon, shows

the contacts to have been made too *close* by the quantity 0″·273 (Wt. 11), the observed semidiameter being too small by that amount. The final result shows unmistakeably that the effect of the cloud through which this set was observed had been to cut off the sharp cusp altogether, and to reduce the planet more or less to the oblong figure artificially produced by Mr. Christie.

In the paper to which I have already referred (*Monthly Notices*, vol. xxxiii. p. 562), I have stated that there can be little doubt that the amount of irradiation of the disk of *Venus* varies from day to day with the transparency of the atmosphere. I have only to add, that the preceding observations prove beyond question that such changes occur at much smaller intervals, and that near the hour of sunrise or sunset are of such magnitude as to require careful elimination in all observations of accuracy. Finally, we may conclude that for the determination of solar parallax by the method suggested by MM. Krüger and Dunkin, each limb of the planet will require to be observed simultaneously or nearly so, in order to evade this peculiarity; and that had this been provided for at both northern and southern stations a valuable result would most probably have been obtained.

Orwell Park Observatory,
1876, *December* 12.

Observations of Shooting Stars, April to December, 1876.

By W. F. Denning, Esq., F.M.S.

(*Communicated by the Rev. R. Main, M.A., F.R.S.*)

The following list of 51 radiant-points were deduced from the paths of 766 shooting stars observed and registered at Bristol during the nine months, April to December, 1876. About 1,050 were seen altogether within this period, but some of them (including a number of Perseids, Geminids, etc.) were not recorded, as their radiants had already been indicated with sufficient accuracy from other paths; and the remainder were not well seen, and accordingly had to be rejected. Previously to October my observations were made irregularly, and not often continued for long periods, but during the last three months of the year the sky was watched on every fine night for several hours, generally before midnight. This will account for my having seen many more meteors in the autumnal months than in the spring and summer. In October, November, and December, during watches amounting in the aggregate to 69½ hours, 532 meteors were seen, and 447 of them registered. Of the total number observed, 322 were noted in 49 hours' watching before midnight, and 210 of them in 20½ hours after midnight (chiefly between 3 and 6 A.M.), so that the rate of frequency A.M. greatly exceeded that P.M., and this was especially marked in November. During the preceding months I did very little work

A.M., and have no data to make the same comparison. The chief showers of the period under review were the Perseids (August 10), the Geminids (December 12), the Cassiopeids (July–August), the Draconids (July–August), the Muscids (October 15), the Taurids I. (November 8), the Taurids II. (December 6), the Aurigids (November and December 13), the Leonids minor (November 25–28), etc. About 40 of the positions included in the list are redeterminations of showers already known or suspected, and in regard to the latter these confirmations will be useful. The remainder appear to be new, and were principally observed in the mornings of November and December, and one of them (a bright and somewhat active display of slow meteors) was seen in the evenings—notably on December 6, when it supplied nearly one-half of the visible shooting stars, as did the Geminids on the night of December 12. A feeble and very late return of the Leonids was observed on the nights of November 19–20 (or A.M. 20–21), but cloudy weather had prevented a look-out on the few preceding nights. From the same cause the Lyraids (April 19–20) entirely eluded me. The Orionids (October 17–19) appear this year to have been but feebly shown, and I saw few of them; but there was much cloudy weather at about that time also, wholly preventing a watch on several nights, and thus the maximum of the shower may have escaped me, as in other cases, for from the results of a single year's observation little can be expected to be done in determining durations and intensities of meteor showers, and some of the brightest and most transient will pass altogether unseen. It is only by observation extending over many successive years that so much has already been learned of these features in regard to many of the leading showers. The dates I have given in the list are those within which shooting stars continued to diverge from the radiants mentioned, and do not pretend to show the absolute periods over which the showers extend, though in some cases this is very near the truth. The list does not include some extremely feeble or suspected radiants, supplying 3, 4, or 5 meteors each, which I have held over and will endeavour to confirm another year. 660 shooting stars are included in the 51 radiant points actually specified, which comprised a large proportion of small meteors, the relative magnitude of the aggregate number registered during the nine months being :—

>1st mag. and= ♃ or ♀	=1st mag.	=2nd mag.	=3rd mag.	=4th mag.	=5th mag.	and—total.
29	55	150	182	234	116	=766

Many fine meteors (including several fireballs) were seen in August (chiefly Perseids), and in December (chiefly Geminids), but in the spring months and in October they were generally very small, and the great majority 3rd–4th mag. In the list I have given the probable number of shooting stars recorded as belonging to each radiant, as this is an important detail, not only as showing the intensity of the shower, but also the value of the position deduced. I have added a column, indicating the

observed specialities of the meteors of each shower, though, obviously, not much can be done in this respect from a single year's work, but it may lead to something more definite and satisfactory being attempted and followed out in the same direction in future years. The descriptions are not by any means to be held as conclusive (for the materials were often scanty, and sometimes uncertain), but as applying only to those members of the different systems that really came under observation, and, except in regard to the more active showers, they may not have afforded a fair sample of the whole. Moreover, the appearance of a meteor is dependent in a great measure upon the position of the radiant point with respect to the apex of the Earth's way. Again, when near the radiant the path is much foreshortened, and the apparent velocity much below the average of the same shower, and *vice versâ*. A white meteor on the horizon will often look ruddy, etc., but, notwithstanding these difficulties, the special features of certain showers are strongly marked and distinct from those of neighbouring ones, and it is an important element to consider, inasmuch as it frequently occurs that contemporary radiants lie near together (or in the same backward prolongation of a meteor's track), and it is sometimes impossible to accord the true focus, unless such details are noted and taken into the account. In some systems these specialities of appearance or motion are strikingly evident, and serve (almost as unerringly as direction of path) to indicate the real centres of emanation. Thus, as instances of extreme velocity, there are the Polarids (September–October), Gemellids (October–November), Draconids, etc.; and as samples of slow motion, the Aquilids (July–August), the Piscids (September–October), the Geminids (December), etc. In the same column I have also given in a few instances the dates of observed maximum or greatest activity.

I have subjoined a list of the observed paths of 85 bright shooting stars recorded during the nine months. These will be useful to compare with the observations of others who may have seen some of them and can afford materials for the calculation of the heights, etc. The magnitudes given are intended to show the *maximum* brilliancy, and the comparisons are with planets and stars of the 1st mag. I have endeavoured to give the *direction* of the paths with as much accuracy as possible, as this is important in the finding of the true radiants, a column of which I have affixed, indicating them. Some details of motion and appearance are also added, but these are somewhat incomplete, especially those relating to colour. Generally, however, I found the slow meteors more or less ruddy, while the rapid ones appeared almost invariably white. Several fine meteors, apparently from the radiant in *Gemini* (36), belonged to the latter class, while others (of the same system?) were noted very slow and red. This anomaly may perhaps be explained by the assumption of a double contemporary shower in *Gemini*, as in the case of the Perseids and Cassiopeids (August), and the Leonids and Leonids minor (November).

List of 51 *Radiant-Points of Shooting Stars observed during April–December* 1876.

No. Jan. 1877.	Date of Observation.	Radiant-Point. R.A. °	Dec. N. °	Name or Position of Shower.	No. of Meteors.	Notes.
1	March 16—April 22	142	49	θ Ursids	6	Meteors small; rapid; a feeble radiant.
2	April 11—May 21	241	24	Coronids	8	Small; white; rapid; no streaks; accurate.
3	April 11–22	230	38	μ Boötis	8	Small; not rapid; accurate.
4	April 13—May 19	207	48	η Ursids	13	Small; short; rapid; an active shower.
5	April 13–22	194	30	Coma Berenicis	7	Small; max. April 15.
6	April 13–22	195	2 S.	Virgo	10	Rather bright; slow; an active shower.
	April 17—May 2	207	7 S.	κ Virginis	5	Small; probably same as last with mean $=201°$ 4° S. 15 meteors.
7	April 14—May	277	57	Draconids	6	Small; short, and very rapid; white.
8	May	221	6 S.	Libra	6	Approximate; a feeble shower.
9	July 16—Aug. 25	330	70	Cepheids	18	Small; white; very rapid; like *Draconids* (12); max. July 19–20; an active shower.
10	July 16—Aug. 14	18	63	Cassiopeids I.	28	Very bright; rapid; with streaks like *Perseids* (16); max. July 24; an active shower.
11	July 16—Aug. 25	349	24	Pegasids	8	Very slow; feeble.
12	July 16—Aug. 16	284	57	Draconids	21	Small; white; very rapid; max. July 16–18; an active shower.
13	July 16–25	337	7 S.	Aquarids	4	Bright streaks; rather slow; continued in September.
14	July 16—Sept. 17	298	2	Aquilids	14	Bright; very slow; ruddy; continued in September; a fine shower.

15	July 16—Aug. 16	340	42	Lacertids	7	Small; white; rapid; no streaks or trains. Mean of the 3 showers = 344° + 42°; 17 meteors July 16—Nov. 20.
	Sept. 16—Oct. 25	346	44	,,	6	
	Nov. 8–20	344	42	,,	4	
16	Aug. 5–12	43	59	Perseids	43	Very bright; rapid; bright streaks; max. Aug. 10; very fine shower.
17	July—Aug.	6	27	α Andromedæ	7	Rapid; fairly accurate; feeble.
18	July—Aug.—Sept. 20	313	41	Cygnids	8	Rapid; white.
19	Sept. 17—Nov. 8	15	11	Piscids	17	Bright; very slow; ruddy; trains; mean of 2 showers; continued in December; active shower.
20	Sept. 18—Oct. 21	14	50	Cassiopeïds II.	13	Small; rather slow; active shower; mean = 15° + 52°; 20 meteors.
	Nov. 7–8	17	53	,,	7	
21	Sept. 17—Oct. 25	317	57	Cepheids	10	Small; very rapid; white; mean of 2 feeble showers.
22	Sept. 20—Oct. 29	161	84	Polarids	7	Very, very rapid; white; position approximate.
23	Sept. 20—Oct. 25	31	37	Triangulum	9	Probably same shower, with mean at 35° + 39°; feeble.
		40	40	β Persei		
24	Sept. 20—Oct. 25	46	26	Muscids	19	Small; rapid; white; max. Oct. 15; an active shower in October.
25	Oct. 13—Nov. 20	85	33	θ Aurigids	7	Small; rather slow; ruddy; possibly same as 37.
26	Oct. 13–25	48	71	Camelopardus	7	Small; somewhat slow like *Cassiopeïds* II.; mean of 2 feeble showers.
27	Oct. 13—Nov. 20	125	47	Lynxids	17	Rapid; white; streaks; max. Oct. 29.
28	Oct. 14–17	38	12	μ Ceti	5	Very slow; a feeble shower; probably same as *Piscids* (19).
29	Oct. 14–25	90	58	δ Aurigæ	6	Bright; rapid; a feeble shower; rather uncertain.

No. Jan. 1877.	Date of Observation.	Radiant-Point. R.A. °	Dec. N. °	Name or Position of Shower.	No. of Meteors.	Notes.
30	Oct.	358	26	α Andromedæ	7	Bright; slow; approximate.
31	Oct. 17–25	88	17	Orionids	8	Bright, with streaks; max. Oct. 17–19.
32	Oct. 21–29	61	18	Taurids I.	6	Bright; not rapid; sometimes with streaks; max. Nov. 8; a fine active shower; mean of the 3 positions = 60° + 19°; 25 meteors.
	Nov. 8	58	16	,,	8	
	Nov. 19–20	62	22	,,	11	
33	Oct. 25—Nov. 20	110	23	Gemillids	11	Small; very, very rapid; max. Oct. 30; quite distinct to No. 36.
34	Nov. 8–20	69	66	H. 17 Camelopardi	8	Small; rather slow; continuation of No. 26; max. about Nov. 19-20, or Dec. 6; an active shower.
	Dec. 4–8	70	67	,,	6	
35	Nov. 20–28	78	43	Aurigids	9	Small; rapid; white; max. Dec. 13; mean of the 2 showers 79° + 46°; 21 meteors.
	Dec. 8–14	79	49	,,	12	
36	Nov. 21—Dec. 8	103	31	Geminids	20	Very bright; slow; often ruddy, with streaks; max. Dec. 12; mean of the 2 showers, 106° + 32°; 44 meteors; a very fine shower.
	Dec. 11–21	109	33	,,	24	
37	Nov. 22—Dec. 8	80	23	Taurids II.	20	Bright; very slow; max. Dec. 6; fine shower; new.
38	Nov. 19–20	149	22	Leonids	5	Rapid; white; bright streaks; a feeble and late return of the great shower; max. 1866.
39	Nov. 8—Dec. 13	140	65	o Ursids	16	Rapid; white; mean of 2 showers.
40	Nov. 7–25	299	50	Cygnids	5	A feeble shower.
41	Nov. 20—Dec. 13	155	36	Leonids Minor	26	Bright; rapid; white; with streaks like *Leonids* (38); a very fine a.m. shower.

42	Nov. 20—Dec. 13	342	65	Cepheus	14	Somewhat slow; new (?); rather uncertain, and perhaps confused with *Cassiopeïds* (20); and *Cygnids* (40).
43	Nov. 21—Dec. 20	208	43	η Ursids	17	Small; short; rather swift; max. Nov. 26; an active shower; new.
44	Nov. 20—Dec. 12	208	71	β Ursæ Minoris	11	A feeble shower; new; a.m.
45	Nov. 25–28	212	18	α Boötis	7	Small; feeble; max. Nov. 28; a new a.m. shower.
46	Nov. 25—Dec. 21	148	2	Sextantids	11	Bright; very rapid; white; with streaks like *Craterids* (47); somewhat feeble; a.m. new.
47	Nov. 25—Dec. 21	165	6 S.	Craterids	11	Bright; very rapid; white, with bright streaks; a fine shower; max. Dec. 21 (?); new; distinct from preceding; a.m.
48	Nov. 25—Dec.	187	37	Canes Venatici	6	Small; rather slow; uncertain, and perhaps confused with Nos. 43 and 50.
49	Nov. 25—Dec. 13	112	13	β Canis Minoris	7	A feeble shower.
50	Nov. 27—Dec. 12	179	29	Coma Berenicis	8	Small; short; not rapid, like No. 43; max. Nov. 27; new; a feeble a.m. shower.
51	Dec. 12–21	221	53	Quadrantids (?)	8	Rather slow; white; streaks.

List of the Observed Paths of 85 Bright Shooting Stars recorded during the Nine Months, April to December 1876.

No.	Date. 1876.	Mean Time. h	m	Magnitude.	Path From R.A. °	From D.N. °	To R.A. °	To Dec. N. °	Length of Path.	No. of Radiant in List.	Notes.
1	April 13	10	3	1	206	50	213	73	23	6	Slow; no streak.
2	,,	10	52	1	251	66	248	50	15	Polaris?	Slow; no streak.
3	14	8	26	1	197	37	226	26	34	Ursa	Very slow, 2½ secs.; rapid at first, then slow, coming almost stationary at the end.
4	,,	9	48	α Lyræ	150	12 S.	131	4 S.	21	?	Rather doubtful path.
5	15	8	31	> ♀	90	24	52	31	34	6?	Pear-shaped fireball; rather swift; white; no streak; rather uncertain direction.
6	20	10	45	1	235	10	250	17	15	6	Very slow; in clouds.
7	22	9	58	1	290	43	316	47	19	α Lyræ	Slow; white.
8	,,	10	28	1	245	13	256	18	11	6	
9	25	9	51	1	13	83	32	68	16	?	Not rapid.
10	May 8	9	17	> 1	281	40	312	51	24	6 or 8	Slow; no streak.
11	10	10	58	1	278	41	296	56	18	α Ophiuchi	Rather doubtful path.
12	11	9	56	1	236	53	216	64	16	,,	
13	July 15	11	5	1	251	49	237	44	11	12	Very rapid; white; no streak.
14	16	10	30	1	240	18	221	20	18	14	Slow; streak.
15	,,	11	17	1	260	80	225	67	15	10	Rapid; streak, 2 secs.
16	18	11	20	> 1	211	49	206	18	31	10	Rapid; bright streak.
17	19	10	58	♃	346	25	337	12	20	10	Not very rapid; streak 1½ sec.
18	20	11	29	1	341	6	335	8 S.	15	10?	Streak 1½ sec.
19	,,	11	42	1	338	32	342	21	11	9	Rapid; no streak.

20		,,	11	50	> ♃	337	7 S.	346	18	26	Aquarius	Rapid; sparks and streak.
21		21	10	26	♀	306	27	317	49	24	14	Rather slow; streak 2 secs.
22		24	10	39	1	268	79	231	67	15	10	Bright streak.
23		,,	10	44	> 1	253	79	225	67	14	10	Bright streak.
24		,,	11	28	1	344	11	356	39	30	13	Rather slow; streak.
25		,,	11	34	♃	38	53	55	39	19	12	No streak.
26		25	10	55	1	276	4	275	5 S.	9	α Lyræ	Rapid; white; no streak.
27		,,	11	19	1	326	23	345	31	18	14	Very slow; streak.
28		31	9	43	Sirius	284	10	286	10 S.	20	α Lyræ	Rather swift; no streak; clouds.
29	Aug.	5	10	12	1	62	71	95	69	11	10	
30		,,	10	12	♃	20	47	8	38	23	16	Bright streak.
31		,,	10	40	♃	199	54	207	19	35	16	Not very swift.
32		8	10	33	1	44	46	44½	37	9	10	Streak.
33		,,	11	20	1	26	23	25	11	12	16	Rapid.
34		,,	11	57	♃	6	25	356	39	16	Pegasid	Not very rapid; bright streak.
35		10	9	28	> ♃	53	79	214	74	27	16	Rapid; streak 2 secs.
36		,,	9	54	2 × ♀	85	78	183	68	27	16	Rapid; streak for 5½ minutes, at about 151° + 78°.
37		,,	11	59	1	50	20	51	14	6	16	Rapid.
38		,,	12	59	♃	27	20	23	11	10	16	Rapid.
39		,,	13	49	1	101	76	161	71	17	16	Rather uncertain.
40		,,	14	28	1	219	84	220	71	13	16	Rapid.
41		,,	15	13	1	15	22	9	7	16	16	Rapid.
42		11	10	27	1	315	9	307	3	15	...	Rapid; streak.
43		,,	10	38	♃	151	69	170	53	19	16	Rapid; streak.

No.	Date. 1876.	Mean Time. h	m	Magnitude.	Path From R.A. °	From D.N. °	To RA. °	To Dec. N. °	Length of Path.	No. of Radiant in List.	Notes.
44	Aug. 11	11	20	> ♀	196	68	210	47	22	16	Rapid; streak 1 minute.
45	„	13	50	1	108	62	128	55	12	16	Rapid; no streak.
46	14	11	35	1	212	42	204	36	9	12	Shone out like a star almost stationary at the end.
47	15	9	26	♀	208	25	186	23	20	14	Very slow; pear shaped.
48	21	9	20	1	179	51	171	46	7	12	Rapid; rather doubtful.
49	24	9	20	1	37	64	36	74	10	24	Streak.
50	Sept. 10	8	15	1	40	54	6	60	19	α Aurigæ	Rather slow; bright streak.
51	19	10	14	4	11	1	8½	2½ S.	5	19	Very short and slow; 2½ secs. near its rad. bright streak 3 minutes.
52	20	9	47	1	22	42	356	43	19	23	Rapid; streak.
53	Oct. 13	10	13	1	64	53	83	55	12	23	Rapid; no streak.
54	14	11	19	4	43	22	30	2 S.	27	29	Rapid; long streak.
55	15	6	17	1	7	24	18	22	10	30	Very, very slow; twilight.
56	21	7	6	1	336	1	329	9 S.	12	30 (?)	Rapid; no streak.
57	„	11	6	1	21	11	25	2	10	30	Slow.
58	Nov. 1	8	35	4	347	18	348	9 S.	28	42	Slow; full moon; rather doubtful.
59	7	8	15	1	88	67	104	65	7	34	Rather slow; streak.
60	8	5	6	> ♀ (?)	236	50	241	35	16	32	Very slow; streak; seen in daylight; uncertain.
61	„	6	35	> 1	339	29	289	9	50	32	Rather slow; 3 secs.; streak.
62	„	6	57	1·5	329	30	284	10	46	32	Not swift.

63	„	8	59	1	8	19	346	17		20	32	Streak; 5 secs.
64	9	8	58	1	44	6	32	4	S.	16	32	Doubtful path.
65	20	7	27	1	79	50	103	64		19	32	Not rapid; streak.
66	„	8	37	1	20	10	25	14	S.	25	42	White; rapid; uncertain.
67	25	17	31	> 1	248	52	268	44		16	41	Rapid; white; bright streak.
68	26	16	32	1	145	67	220	59		32	37	Slow; red; 2 maxima.
69	27	16	9	1	159	10	S.	184	18		25	49	Rapid; white.
70	28	17	18	1	179	74	235	67		14	39	Very rapid; white.
71	„	18	5	1	175	34	184	33		8	41	Very rapid.
72	Dec. 6	7	8	1	90	35	96	38		5	37	Very slow; near rad.
73	„	9	35	1	103	5	104	3	S.	8	36	Red; streak.
74	8	10	16	4	118	44	128	48		8	36	Slow; streak $2\frac{1}{2}$ secs.
75	11	11	17	> 1	55	4	45	3	S.	12	36 (?)	Rapid; white.
76	12	6	54	1	119	78	266	76		24	36	Not rapid; streak.
77	„	8	15	less than ♀	106	37	102	43		7	36	Very, very slow; ruddy; streak 10 secs.
78	„	8	47	1	156	52	133	42		18	51	Rapid; white.
79	„	16	2	1	183	41	200	37		14	36 (?)	Rapid; white.
80	„	18	18	4	202	19	218	12		10	36 or 41	Rapid; streak 6°, 7 sec.
81	„	18	34	1	199	13	S.	218	24	S.	21	36	Slow.
82	13	10	58	1	144	12	162	17		17	Monoceros	Slow.
83	19	10	20	> ♀	43	13	24	4		21	36	Slow, 1·5 sec.; cloudy.
84	21	10	31	4	144	33	162	31		16	36	Slow.
5	„	14	53	1	142	28	122	7		27	51	Very rapid, white.

Observations of Occultations of Stars by the Moon, and of Phenomena of Jupiter's Satellites, made at the Royal Observatory, Greenwich, in the year 1876.

(*Communicated by the Astronomer Royal.*)

Occultation of Stars by the Moon.

Day of Obs. 1876.	Phenomenon.		Telescope.*	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
Feb. 2	Disapp. of	27 Arietis	E. Eq.	140	Dark	6 30 19·3	L
April 7	,,	Piazzi XII. 111	,,	,,	,,	8 27 53·9	C
,,	,,	*f* Virginis	Altaz.	100	,,	11 38 21·7	C
11	Reapp.	*b* Scorpii	,,	,,	,,	11 56 51·2	C
May 5	Disapp.	50 Virginis	E. Eq.	140	,,	12 0 43·0	A D
Aug. 13	,,	χ Tauri	Altaz.	100	Bright	12 19 20·5	G
Nov. 29	,,	47 Arietis	E. Eq.	140	Dark	7 57 28·4	T
,,	,,	47 Arietis	S.E. Eq.	220	,,	7 57 28·2	M

Phenomena of Jupiter's Satellites.

Day of Obs. 1875.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time from N.A. h m s	Observer.
Apr. 8	I (*a*)	Occ. reapp. first cont.	S.E. Eq.	130	13 18 28		
,,	I	,, bisection	,,	,,	13 20 52	13 18	M
,,	I	,, last cont.	,,	,,	13 26 59		
15	I	Ecl. disapp.	E. Eq.	140	12 11 56·3	12 12 1·5	R P
20	II (*b*)	Tr. eg. first cont.	,,	,,	11 28 58		
,,	II	,, last cont.	,,	,,	11 31 12	11 26	T
May 1	I (*c*)	Ecl. disapp.	,,	,,	10 28 11·4	10 28 2·3	A D
,,	I (*d*)	Occ. reap. first cont.	,,	,,	12 59 37		
,,	I	,, last cont.	,,	,,	13 1 41	13 0	A D
4	II	Tr. ing. bisection	,,	,,	13 29 36		
,,	II	,, last cont.	,,	,,	13 31 51	13 28	P
6	II (*e*)	Occ. reapp. first cont.	,,	310	10 0 19	10 3	C
9	I (*f*)	Tr. eg. last cont.	,,	140	11 53 10	11 51	A D
20	II	Occ. disapp. first cont.	,,	310	11 59 21		
,,	II	,, bisection	,,	,,	12 1 50	12 1	A D
,,	II	,, last cont.	,,	,,	12 3 20		

* The clear aperture of the object-glass of the S.E. Equatoreal is $12\frac{3}{4}$ inches, of the East Equatoreal 6·7 inches, of the North Equatoreal 4·1 inches, and of the Altazimuth $3\frac{3}{4}$ inches.

Day of Obs. 1875.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time from N.A. h m s	Observer.
May 29	II	Tr. eg. first cont.	„	„	11 45 53		
„	II	„ bisection	„	„	11 47 22	11 49	C
„	II	„ last cont.	„	„	11 49 7		
June 24	I (*g*)	Tr. eg. last cont.	„	140	11 29 46	11 14	L
July 3	III	„ last cont.	„	„	11 9 12	11 10	T

Notes.

(*a*) The limb of *Jupiter* was very tremulous.

(*b*), (*d*), (*e*) The limbs of the planet were badly defined.

(*c*) The first diminution of brightness was observed $2^m\ 15^s$ before the time here recorded.

(*f*) The observation was not satisfactory.

(*g*) The image of *Jupiter* was very bad. The recorded time is evidently erroneous.

The initials L, C, AD, M, T, G, P, and RP, are those of Mr. Lynn, Mr. Criswick, Mr. Downing, Mr. Maunder, Mr. Thackeray, Mr. Graham, Mr. Pulley, and Mr. Pett respectively.

Royal Observatory, Greenwich,
1877, *January* 13.

Stars to be compared in R. A. with Mars 1877, *for Determination of the Parallax of Mars.*

(*Communicated by the Astronomer Royal.*)

The stars in the accompanying list have been selected from those given on the chart in the *Monthly Notices* for 1875, November, as being suitable for equatoreal observations of the differences of their R. A. and that of *Mars*, east and west of the meridian. They have been arranged in pairs, one star preceding and the other following *Mars;* and as a fresh setting of the Equatoreal in N.P.D. will usually be required for each object, an interval of at least three minutes of time is allowed between the transit of *Mars* and that of either star. In some cases, however, a pair of stars can be found passing through the same field as *Mars*, and here a much smaller interval will be sufficient, with the advantage that a larger number of comparisons can be made, the sets being repeated in more rapid succession. Such pairs of stars are denoted by an asterisk. In order to eliminate as far as possible the effect of error of adjustment of the Equatoreal, stars have been selected at about equal distances north and south of *Mars*, and in some few instances where this was not practicable,

two stars on one side have been given with a view to securing a due balance, it being intended that these two stars should be observed alternately in combination with *Mars* and the other star. Preference has been given to the brighter stars, but there is such a paucity of stars in this region that it has sometimes been necessary to go as low as the ninth magnitude.

The plan of observation requires a firmly-mounted Equatoreal, which can be securely clamped in Right Ascension, and provided with a transit eyepiece having a system of parallel meridional wires at convenient intervals. A number of sets of transits of *Mars* and a pair of stars should be taken in as rapid succession as possible in the evening, when *Mars* is east of the meridian and as far from it as practicable; and a corresponding number of *Mars* and the same pair of stars in the early morning, when *Mars* is far to the west, the Equatoreal being firmly clamped for each set. Both limbs of *Mars* are in all cases to be observed, over alternate wires, or otherwise, as may be found convenient, care being taken that the limb (whether first or second) observed over any particular wires in one set be observed over the other wires in the next set. The same pair of stars must be observed in the morning and evening (as has been mentioned), and when a change occurs from one day to the next, both the old and the new pair should be observed alternately on one morning or evening at least. If different observers take part in the work, care should be taken that each observer is charged as often with morning as with evening observations.

The value of the observations made at any particular station will depend largely on the interval between the evening and morning sets of comparisons; and the choice of stations is determined mainly by consideration of the available time-interval during which *Mars* is far enough above the horizon and the Sun far enough below to allow of satisfactory observations being made. Taking these "horizon allowances" as $1^h\ 20^m$ for lat. 50° N., $1^h\ 0^m$ for lat. 15° N., and $1^h\ 10^m$ for lat. 35° S., the "available time-interval" has been computed for these three latitudes; and the following table has been formed, showing, at intervals of seven days, the square of the quantity $\frac{1}{\text{dist. of } Mars}$ × cos. of station's latitude × available time-interval, which may be considered as a roughly approximate value of the square of the parallax factor, and which gives the combining weight of these observations in the determination of the Sun's Equatoreal Horizontal Parallax.

(*Parallax Factor*)^2

			Latitude 50° N.	15° N.	35° S.
1877	July	22	23	155	180
		29	34	202	216
	August	5	50	259	269
		12	72	329	325
		19	97	405	383
		26	126	487	444
	Sept.	2	156	563	492
		9	152	586	480
		16	141	496	413
		23	125	410	330
		30	104	330	256
	Oct.	7	86	263	194
		14	71	208	144
		21	57	163	106
		28	50	129	78

Pairs of Stars to be compared in R.A. with Mars.

(The Nos. are those of Weisse's Bessel, *Cat. Stell. in Zonis Regiomontanis.* The mean places of the Stars for 1877 are given in the *Monthly Notices*, for 1875, November.)

1877.		
July 25	322, 565	427*, 508*
26	,,	,,
27	427, 586	
28	,,	
29	,,	
30	427, 619, 629	
31	,,	
Aug. 1	,,	
2	,,	
3	,,	
4	,,	
5	,,	
6	,,	
7	,,	
8	,,	
9	,,	
10	,,	

1877.			
Aug. 11	427, 619		
12	,,		
13	,,		
14	,,		
15	427, 583		
16	,,		
17	,,		
18	377, 583		
19	,,		
20	,,		
21	377, 497		
22	,,		
23	315, 497		
24	315, P. XXIII. 109		
25	,,		
26	265, 497		
27	265, 402	309*, ✻ (R.A. 19^h 55^m N.P.D. 101°22′)*	
28	,,	286*, 385*	
29	ψ^3 Aquarii, 402, 403		
30	,,		
31	ψ^2 Aquarii, 373	185*, 309*	
Sept. 1	Lal. 45504, 309	,,	
2	,,	,,	
3	57, 265	Lal. 45504*, 309*	
4	,,	,,	
5	,,	,,	
6	49, 228, 270	57*, Lal. 45504*	
7	1276, 185	,,	
8	,,	,,	
9	1261, Lal. 45504	1261*, 57*	
10	,,	,,	
11	1204, 57	,,	
12	,,	,,	
13	,,	,,	
14	1129, 12, 14	1204*, 1261*	
15	,,	,,	
16	,,		
17	1079, 1261	1129*, 1204	
18	,,		

1877.				
Sept. 19		966, 1204		
20			966*, 1129*	
21			,,	
22		74 Aquarii, 1165	,,	
23		,,	,,	
24		,,	,,	
25		,,	,,	
26		,,	,,	
27	918, 1129	935, 1156	70 Aquarii, 1079	966*, 1129*
28		70 Aquarii, 1079		
29		,,		
30		,,		
Oct. 1		,,		
2		,,		
3		,,	74 Aquarii (conjunction)	
4		,,	,,	
5		,,	,,	
6		,,		
7		,,		
8		,,		
9		,,		
10		70 Aquarii, 1047, 1079		
11		,,	926*, 1007*	
12		,,	,,	
13		,,		
14		70 Aquarii, 1065		
15		910, 1047	70 Aquarii, 1122	
16		70 Aquarii, 1122	946*, 70 Aquarii*, 1020*	
17		70 Aquarii, 1120	977*, 946*, 1020*, 1017*	
18		,,	994*, 933*, 1017*	

Royal Observatory, Greenwich,
1877, *January* 13.

On O. M. Mitchel's Observations at Cincinnati.

By Cleveland Abbe, Esq.

In a note to his recently-published "Reference Catalogue" Mr. Knobel calls attention to the fact that copies of Mitchel's *Sidereal Messenger* are very rare in England, and to the Supplementary note in *Nature* (November 9, page 49). I would add,

that complete sets of this interesting periodical are almost equally as rare in America.* Rarer still is to be found nowadays the excellent text-book for schools and hand-book for amateurs, published in 1849, in Cincinnati, New York, as "Mitchel's edition of Burritt's *Geography of the Heavens*." In this book Mitchel published numerous notes based on the work done during 1845–48 at his Observatory, and I have thought it may interest members of the Astronomical Society if I copy from it for their use the record of double star positions observed at Cincinnati. These few figures, however, convey but a faint idea of Mitchel's activity during those years: in my annual reports, 1868, 1869, and 1870, I have given a nearly full list of his publications, and expressed the hope that I should be able to prepare for publication such of his observations (especially the very extensive series of zones of faint stars) as gave promise of being useful; and although this is now become a very difficult matter, owing to the death of Mitchel and his faithful assistant Twitchel, yet possibly my successor may be induced to undertake it.

In the accompanying table reference is given in the last column to the page of Mitchel's edition of Burritt. I have also included the name of Nebulæ, etc., concerning which Mitchel gives some notes as to their appearance at Cincinnati; these notes are generally somewhat general and unsatisfactory in their nature, but I shall be happy to communicate them in full if desired. I fear lest an occasional typographical mistake may have crept into the measurements here given; but possibly these may at some future time be rectified if ever the original observer's note-book can be found.†

Washington,
1876, *December* 15.

Observations of Double Stars, by O. M. Mitchel, made between May 1845 *and May* 1848, *with the* 12*-inch Refractor, at Cincinnati.*

(*From Mitchel's "Geography of the Heavens," New York,* 1849.)

No.	Constellation and Object.	R.A. h m	Dec. ° ′	Position-Angle. ° ′	Distance. ″	Epoch.	Page.
1	38 Piscium	0 9	+ 7 59	235 59	4·646	1847·65	54
2	55 „	0 31	+20 33	191 52	7·014	1847·65	54
3	τ Cassiopeiæ	0 39	+50 34	146 25	2·24	1847·60	49
4	η „	0 39	+56 57	101 20	8·59	1847·60	49
5	65 Piscium	0 41	+26 50	297 32	...	1847·65	54

* The Astor Library, in New York City, possesses a few of the last published numbers, which are, I believe, wanting in all the other sets that I have hitherto seen.

† The names of Nebulæ are omitted from the Table as printed, and the Double Stars have been rearranged in order of Right Ascension.—Ed.

No.	Constellation and Object.	R.A. h m	Dec. ° ′	Position-Angle. ° ′	Distance. ″	Epoch.	Page.
6	36 Andromedæ	0 46	+22	330 14	1·050	1847·70	39
7	ψ Cassiopeiæ (A & B)	1 14	+67 14	102 37	30·394	1847·60	49
8	„ „ (B & C)	„ „	„ „	253 7	32·856	1847·60	50
9	γ Arietis	1 44	+18 30	175 37	9·184	1847·65	60
10	α Piscium	1 53	+ 1 59	330 3	...	1847·65	55
11	γ Andromedæ	1 54	+41	110 0	0·40	1846·60	40
12	γ Virginis	12 33	− 0 34	357 28	3·09	1847·60	116
13	Comæ Ber. (A & B)	12 45	+22 7	40 4	1·316	1847·57	135
14	„ (A & C)	„ „	„ „	125 31	...	1847·57	135
15	84 Virginis	13 35	+ 4 21	231 5	3·48	1847·06	118
16	π Boötis	14 33	+17 6	96 57	8·28	1847·60	128
17	ζ „	14 33	+14 25	128 24	6·924	1847·62	128
18	ε „	14 38	+27 45	320 50	2·568	1846·66	128
19	ξ „	14 44	+19 46	317 44	6·482	1847·63	129
20	39 „	14 44	+49 22	37 0	4·00	1847·60	129
21	44 „	14 58	+48 16	238 20	3·738	1847·62	129
22	β Scorpii	15 56	−19 21	26 22	13·68	1846·50	147
23	51 ξ Libræ (A & B)	15 58	−10 55	24 52	0·97	1846·48	143
24	„ „ (A & C)	„ „	„ „	74 42	7·16	1846·48	143
25	ν Scorpii (A & B)	16 2	−19 2	37 57	1·2	1846·(?)	146
26	„ „ (½ A B & C)	„ „	„ „	338 29	40·0	1846·(?)	146
27	σ Scorpii	16 11	−25 12	271 5	22·34	1847·60	147
28	α „	16 19	−26 4	90 0	2·5	1845·5(?)	146
29	XIV Piazzi 88	16 20	− 7 45	304 14	5·292	1847·70	186
30	λ Ophiuchi	16 22	+ 2 20	3 42	1·42	1847·65	183
31	ζ Herculis	16 35	+31 53	109 12	1·078	1847·70	163
32	η „	16 37	+39 13	...	inseparable	...	163
33		16 54	+ 8 41	146 57	0·826	1847·70	185
34	μ Draconis	17 2	+54 41	190 57	2·90	1847·70	133
35	36	17 5	−26 21	215 49	4·27	1847·62	185
36	α Herculis	17 7	+14 34	117 36	4·92	1847·62	162
37		17 17	+15 45	62 33	3·654	1847·60	185
38	Draconis	17 25	+50 59	266 20	3·03	1847·70	133
39	τ Ophiuchi	17 54	− 8 10	229 24	0·779	1846·51	183
40	$p = 70$ Ophiuchi	17 57	+ 2 32	120 45	5·53	1847·55	183
41	73	18 1	+ 3 58	253 0	1·274	1847·55	185
42	ε Lyræ (A & B)	18 39	39 30	20 25	2·46	1847·60	172
43	5 „ (C & D)	„ „	„ „	149 10	2·55	1847·60	172

No.	Constellation and Object.	R.A. h m	Dec. ° ′	Position-Angle. ° ′	Distance. ″	Epoch.	Page.
44	Aquilæ (B & C)	18 54	− 0 55	76 0	1·576	1847·60	176
45	Aquilæ	18 57	+ 6 18	152 28	9·492	1847·65	176
46	23 Aquilæ	19 10	+ 0 48	12 9	3·57	1847 67	177
47	Aquilæ (A & B)	19 28	−10 46	319 4	2·54	1847·60	176
48	„ (A & C)	„ „	„ „	169 17	...	...	176
49	Aquilæ	19 37	+10 23	276 36	4·33	1847·72	177
50	π Aquilæ	19 41	+11 25	123 9	1·20	1847·66	176
51	α^2 Capricorni	20 9	−13 2	144 11	6·36	1846·67	195
52	ρ „	20 19	−18 20	176 56	3·094	1847·70	195
53	XX Piazzi, 376 Equulei	20 47	+ 3 55	287 45	1·874	1847·65	189
54	ε Equulei (A & B)	20 51	+ 3 41	288 6	0·574	1847·60	189
55	„ „ (A & C)	„ „	„ „	76 25	11·08	1847·60	189
56	λ „	20 54	+ 6 33	227 42	1·9	1847·60	189
57	12 Aquarii	20 55	− 6 27	191 30	8·23	1847·63	192
58	61 Cygni	20 59	+37 58	101 2	17·3	1847·50	167
59	29 Aquarii	21 53	−17 43	242 8	4·466	1847·70	192
60	41 „	22 5	−21 51	120 22	4·326	1847·70	193
61	Pegasi	22 6	+16 24	331 29	8·03	1847·65	188
62	ζ Aquarii	22 20	− 0 50	346 42	3·948	1847·70	193
63	37 Pegasi	22 21	+ 3 37	121 46	0·98	1847·70	188
64	Aquarii	22 34	− 9 8	314 35	1·82	1847·70	193
65	Piscium	23 37	− 0 37	227 33	2·702	1847·65	35

On the Space-penetrating Power of Mr. Lassell's 2-foot and 4-foot Reflectors. By W. Lassell, Esq.

In the *Monthly Notices* for December is a note by M. Otto Struve, in which, quoting from a previously written paper, he says, "The space-penetrating power of Mr. Lassell's new (4-feet) instrument can hardly be estimated superior to that of ours (the Pulkova 15-inch) Refractor." There appears to me to be something so erroneous in this conclusion, that although very averse to controversy, and especially to enter the lists with my very distinguished friend, M. Struve, I crave permission to state my greatly differing opinion, and the grounds on which I have formed it.

To begin with a comparison of the powers of my 2-foot Equatoreal with those of the Pulkova telescope. About the year 1847 and later, I was engaged, as opportunities offered, in a diligent scrutiny with the view of verifying the fainter Satellites

of *Uranus*, presumed to have been discovered by the late Sir William Herschel. It would appear from Professor Struve's communication to the *Monthly Notices*, vol. viii., pages 44 and 139, that he was then engaged in the same careful search; and he announces, with some confidence, his verification or re-discovery of at least one of Herschel's satellites, namely, that whose period was announced by Herschel to be $5^{d}\ 21^{h}\ 25^{m}$, adding that he had no doubt of the identity of the two objects, and that his observations "completely prove the existence of Herschel's first supplementary satellite." Yet the detailed observations at page 46 do not seem to me sufficiently exact or consistent to justify this conviction; and certainly the long series of supplementary observations of the Satellites of *Uranus* has made the conclusion irresistible that this rediscovery must be given up, and that the Pulkova telescope was not equal to the task then set before it.

The interior faint satellites, now recognised as *Umbriel* and *Ariel*, were first certainly seen by me in 1847, but I was not able to give what I thought a sufficiently distinct account of them until 1851; and I would especially direct attention to my letters of the 13th and 29th November in the latter year (*Monthly Notices*, vol. xii., page 15), as proving by the precision, certainty, and frequency with which the objects were seen, that the 2-foot Reflector must have been even greatly superior to the 15-inch Refractor. I may, perhaps, add also the opinion of the late Mr. G. P. Bond, expressed verbally to myself, that my 2-foot telescope was sensibly more efficient than the Harvard Telescope, which may be called a facsimile of that at Pulkova.

I will now refer to vol. xxxvi. of the *Memoirs*, containing the record of my observations at Malta with the 4-foot Equatoreal, as proving the superiority of that telescope in illuminating or "space-penetrating" power, to the 2-foot Equatoreal.

At page 34 an observation of *Uranus* and his Satellites is recorded, together with an expression of my opinion of the comparative efficiency of these telescopes on these objects, and asserting the great superiority of the 4-foot. Again, at page 36, on September 27th there is recorded an observation of δ *Cygni*, in which the 2-foot is again mentioned, with a remark in favour of the 4-foot. Further, at pages 7 and 8, observations of the Satellite of Neptune made on August 2nd, September 22nd, and October 19th, are given, when the satellite was observed nearer to the limb of the planet than it had ever been seen in the 2-foot. Moreover, I may remark that the observation of a faint satellite very near to its primary in two telescopes differing greatly in size, tells disproportionately against the larger one; since the greater brightness of the planet diminishes the sensibility of the eye for detection of the satellites—in addition also to the greater disturbance of the atmosphere with the larger aperture.

Lastly, in further corroboration of the superiority of the 4-foot, I may suggest a comparison of the figured Nebulæ in this volume with such of them as are contained in vol. xxiii.

of the *Memoirs*, in my paper giving observations with the 2-foot.

I conclude with remarking that Professor Struve's unfavourable impression may perhaps in some degree have arisen from his visit to Malta having been made at a time of the year when the atmosphere is occasionally much disturbed by storms, which are of course greatly to the disadvantage of a very large telescope.

Ray Lodge, Maidenhead,
1877, *January* 23.

The Specular Reflexion Hypothesis, and its bearing on the Transit of Venus. By John Brett.

There was a phenomenon observed at the transit of *Venus* (the ring of light at the planet's limb), which, as far as I know, has not hitherto been explained, and my present purpose is to show that the specular reflexion hypothesis has an important bearing on this subject. If, in addition to a burnished reflecting surface, we suppose *Venus* to have a translucent envelope of great density, it appears to me that all the elements necessary for a complete explanation of the mystery are at hand ; at all events, it is possible on these terms to produce a very similar phenomenon experimentally.

In my last I ventured to suggest a reason for believing the surface of the planet to be in a molten or vitrified state.

That suggestion was peculiarly fortunate in having attracted the attention of Mr. Christie, whose investigations afford, at all events, invaluable data for studying the subject, if not (as I believe) a complete confirmation of the hypothesis. *Vide* last Number of the *Monthly Notices*.

The theory of specular reflexion is, of course, perfectly well understood, and its phenomena in the case of *Venus* and the Sun would occur as follow :—At superior conjunction we should see merely a small circular image of the Sun. In the course of the planet's progress in its orbit, this image would move in longitude and extend itself in latitude, assuming a cusped crescent form. Near the time of inferior conjunction it would approach the limb, and present an extremely attenuated rim of light. At transit this rim would completely encircle the disk, and theoretically would never entirely disappear. Even practically, the Sun's light near his limb is so much weaker than at the centre, that it is quite conceivable that the ring, or reflected image, might be observed during the earliest and latest stages of the transit. The position this ring would occupy within the planet's limb can of course be determined with accuracy by a calculation based on the relative diameters of the Sun and planet.

So far the theory is simple, and has been so well understood for ages that no illustration is needed.

It will, however, be perceived that any expansion in latitude of this extremely attenuated ring which might have been ob-

served at transit (and I understand that the photographs prove such to have been the case), would introduce other and more complicated considerations into the problem, indicating, as I suppose it would, the existence of a refractive envelope or atmosphere. Now, any diffusion or extension of the area of the ring would of course weaken the intensity of its light, not to mention the question of absorption. Before contact, however, these considerations would not at all damage the theory. The great difficulty arises when we find a diffused ring of light surrounding the planet whilst actually on the Sun's disk surpassing in brilliancy his direct rays. If there are no theoretical objections to the planet's surface existing in a state of fusion, or at all events, to have so existed, it is not unreasonable to suppose that the metallic constituents of its substance would settle at a lower level than its lighter or vitreous elements: we might thus imagine a molten metallic lustrous surface overlaid and protected by an envelope of glass.

There is, I suppose, no doubt that the lenticular action of an atmosphere of great refractive power would be effective to bend over the limb, and produce in a condensed state, some of the rays which impinge on the planet immediately *beyond* the limb, and in that way it seems to me that a certain degree of increased brilliancy would be produced; but if we are allowed to assume the existence of a vitreous envelope, it is evident that, in addition to the correction of the divergence of such rays as have been reflected from a zone of the burnished surface *immediately* behind the limb, a quantity of light reflected from another zone still further beyond the limb, would be condensed by *interior* reflexion from the surface of the vitreous envelope, acting in the sense of a concave mirror, and produced over the limb towards the Earth, so as to give a luminous halo of greater brilliancy than the Sun itself. The little instrument which I invite the Fellows to look into after the meeting shows that such a result can be experimentally produced.

It consists, first, of a small globe representing *Venus* suspended within a tube; secondly, of a collimator; and, thirdly, of a microscope focussed upon the limb of the little globe. The little globe or model of *Venus* consists of a glass bulb filled with mercury.

When this instrument is directed to a gas-lamp the ring of condensed light is very plainly seen; and I think that although the apparatus is very rudely and imperfectly made, it does all that can be expected of it.

I now ask leave to add one more suggestion, as follows:—

At the next transit it would be worth while for some one with a good telescope and a Dawes-diaphragm to look at the centre of *Venus's* disk for the reflected image of the Earth. If the envelope of the planet has great refractive power, I think it not improbable that it might be seen as a minute nebulous speck of light.

38 *Harley Street, London,*
1877, *January* 12.

An Improved Mode of viewing the Sun.

By Wentworth Erck, Esq.

A Barlow-lens is first employed to enlarge the image, and then, by means of a small, unsilvered, elliptical, plane, glass surface a minute portion of the pencil, forming the enlarged image, is deflected into the eyepiece; the remainder of the pencil, which may be $\frac{97}{100}$ths of the whole, escaping, freely, and therefore without heating, into the open air.

For example: The image formed by my object-glass is an inch in diameter; this is doubled by a Barlow of 8-inches negative focus, while the minor axis of the elliptical reflector is only $\frac{1}{3}$rd of an inch.

Thus it is evident that only $\frac{1}{36}$th of the entire image is transmitted to the eyepiece, and the remaining $\frac{35}{36}$ths escape freely into the open air.

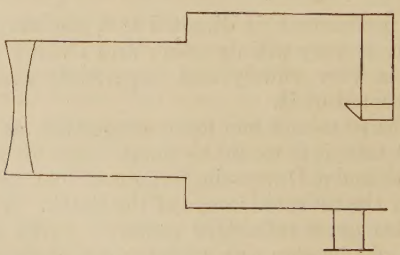
But of the $\frac{1}{36}$th that would reach the eyepiece, only $\frac{1}{10}$th is actually reflected by the unsilvered surface, so that the amount of heat reaching the eye, under these arrangements, is but $\frac{1}{360}$th of that which would reach the eye directly viewing the original image of the Sun.

As it is desirable to be able to examine the edge of the disk in the centre of the field, and also desirable that no part of the pencil should impinge upon metal work, it follows that the clear aperture of the Barlow should be at least twice the diameter of the principal image ; and the tube, carrying the eyepiece, should be four times that diameter.

The most convenient form of reflector is a cylinder cut at an angle of 45°, and having its surface and base polished to prevent escape of heat except at the base. This cylinder is supported on a very light arm, exactly as in a Newtonian.

I can speak from experience of the great advantage of this arrangement, the eyepiece remaining even in summer perfectly cool, with $7\frac{1}{2}$-inches aperture, and the definition unimpaired so long as the telescope is kept accurately following the Sun to prevent his rays striking on the tube.

The subjoined sketch is $\frac{1}{4}$th true size.



Sherrington, Bray,
1877, 5*th January.*